AUTOMATIC SLEEP SCORING BASED ON MODULAR RULE-BASED RESONING UNITS AND SIGNAL PROCESSING UNITS

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***Abstract*- Sleep stage scoring is laborious and requires much expertise. So using expert system for automatic sleep scoring systems is desirable. In this study, we have designed and implemented a multi-staged rule-based reasoning system with augmented functions using communications among RBRU(rule-based reasoning unit). With RBRU not having sufficient information, the unit is designed to ask the previous RBRU and SPU(signal processing unit) to provide more information. With brief information only, the RBRU can score sleep stage with efficiency and exactness in simple cases. If this brief information is not sufficient, additional information tossed from previous unit is combined for enhancing accuracy of sleep stage scoring.**
***Keywords:* sleep scoring, rule-based reasoning, multi-staged**

I. INTRODUCTION

Integrated analysis on the state of sleep through Polysomnography is crucial for diagnosis for sleep related disease. But conventional analog-type Polysomnography systems need tremendous amount of papers and much labor of trained expert. In this sense to equip digital Polysomnography and its following automatic analysis system became trend. In the sleep analysis, sleep stage scoring is the basic analysis and provides integrated information about the sleep state. Generally a sleep stage is scored for one 30 second epoch of sleep. In this study we use hybrid type of expert system, those are rule-based and cased-based.

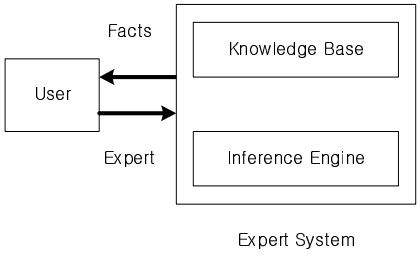

Fig 1. General conceptual schematic of Expert System

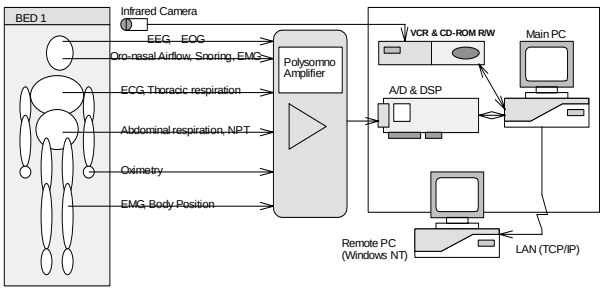

Fig 2. Schematic of total Polysomnography System

II. METHODOLOGY

In this study we used rule-based reasoning that is a kind of knowledge based expert system. To use rule-based reasoning is for mimicking the Rechtschaffen and Kales rule which is the gold standard of sleep stage scoring. And there is another type of expert system, i.e. case-based reasoning for the chance of missing which is caused by the incompleteness of coverage of rule to whole case. This hybrid type is very similar to real visual scoring in the sense that expert follow some rules, i.e. R&K Rules and if he encounter an exceptional case he uses his experience in the past.

1) Rule-based reasoning(RBR)

Rule-based reasoning is a sort of knowledge-based expert system and its knowledge base is rule-base that is consists of sentence structure of IF- THEN. Rule-based reasoning uses facts those are entered by user or already exists in the working memory as the general expert system. Facts those are gathered in such way is pattern-matched with the Conditional Element of the rule, i.e. the IF- part of rule. And if pattern is matched than rule fires. Several rule that consists of rule-base fires in this way and reach the final result consequently. The total schematic and process of general form of rule-based reasoning is shown in fig. 3.

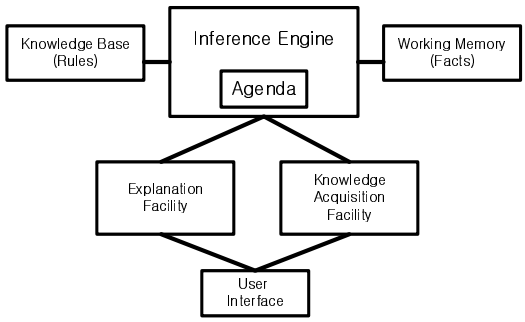

Fig 3. Schematic of Rule-Based Reasoning

2) Case-based reasoning(CBR)

Case-based reasoning is also a sort of knowledge-based expert system and its knowledge base is case-base that is consists of structure of Problem-Solution set. In sleep stage scoring, Problem is consists of the whole abstracted situation, i.e. extracted features to score the stage. And by specific distance measure appropriate for each application, the optimal solution for given situation or problem is founded. In this way the result is induced. Case-based reasoning supplement the shortcomings of rule-based reasoning which could not contain all the rules due to various situations. In this paper the main point of view is concentrated on the

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Automatic Sleep Scoring Based on Modular Rule-Based Resoning Units and Signal Processing Units	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Institute of Biomedical Engineering Seoul National University College of Medicine Seoul, Korea	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
4

optimization of Rule-based reasoning, the explanation for CBR is brief.

3) Modular Rule-based reasoning units and Communication among them

There also exists previous study about modular Rule-based reasoning unit. But in most of them there is no implementation of communication between unit to request information and response to it when given information is not sufficient.

In sleep scoring the rule-based reasoning unit is divided into successively Preprocessing, Single Epoch Reasoning and Multi Epoch Adjusting. In this sense if there is some error in prior reasoning process, the whole following process is influenced by the error. And free communication between module is crucial for chained changes in each process if augmented information is required. So in this study we implemented the modular communication between units.

(1) Communication between SPU and RBSU

We also divided the SPU(Signal Processing Unit) into several module to make it possible to avoid unnecessary calculation in SPU when with brief information extracted from small number of .First extract spectral information od C3 EEG channel. And if alpha activity is dominant we decide the sleep stage is Wake stage. If not, with extracted delta power and delta activity time we decide if sleep stage is sleep Stage3 or sleep Stage4. If not, more analysis on EEG channel will be done to extract the sleep spindle and K-complex those are specific feature of sleep Stage2. And if not, finally checking EMG(electromyogram) and EOG(electroocculogram) to score if sleep stage is sleep Stage1 or REM. In this way if decided sleep stage is definite then other unnecessary routine is not performed.

(2) Communication among RBSUs

As modularization in the SPU modular RBSU is more efficient in the sense of time saving. And for communication to request more information when given information is insufficient, modularization is necessary. And each modular units is organized by one coordinating unit.

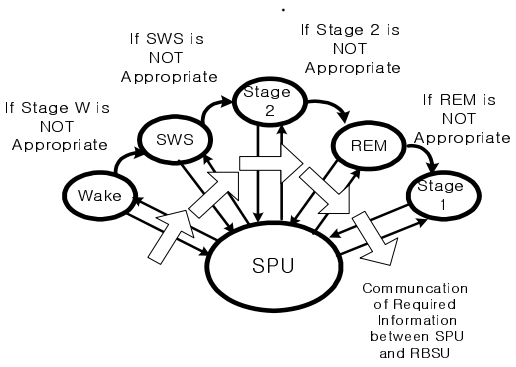

Fig 4. Communication between SPU and RBSU

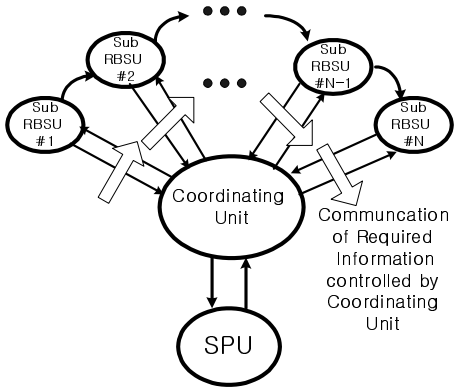

Fig 5. Communication among Modular RBSUs

III. RESULTS

The expected profit of communication is efficiency in time consuming and enhancing the correctness of reasoning. With RBSU(Rule-based scoring unit) not having sufficient information, the unit is designed to ask the previous RBSU and SPU(signal processing unit) to provide more information. First with brief and essential information only, the RBSU can score sleep stage with efficiency and exactness in simple cases. If given information is sufficient to make definite reasoning result then inference engine will stop reasoning. And if this brief information is not sufficient, through the communication between current unit and prior unit, the additional information is tossed from previous unit and it combined for enhancing accuracy of sleep stage scoring. Furthermore saved time in this way allows us to make real-time reasoning and make it possible to gather more augmented information needed to achieve more correct scoring.

Developed system underwent two test. First one is for testing time efficiency with the profit of modularized SPU. Second one is for testing enhancement of correctness based on . But this test was not so properly performed because of incompleteness of smoothing rule to process for large number of 30 second epochs. Therefore not a good knowledge about augmented information required to score ambiguous epoch.
In this sense CBR(Case-based reasoning) is useful. And furthermore Localization in case-DB will make it possible to generate another rule that concerned with augmented information required to make a good scoring in ambiguous case.

Fig 6 and Fig 7 shows the example resulted from application of our algorithm(only with RBSU) to a normal control subject . The effect of modularization is mainly the effectiveness in time consuming.

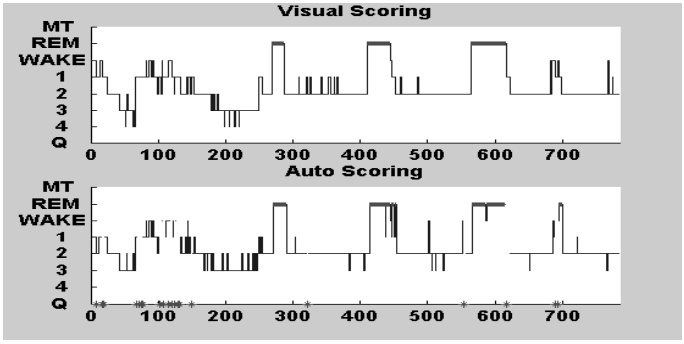

Fig 6. Example Hypnogram of Visually scored and Automatically scored sleep structure of normal control

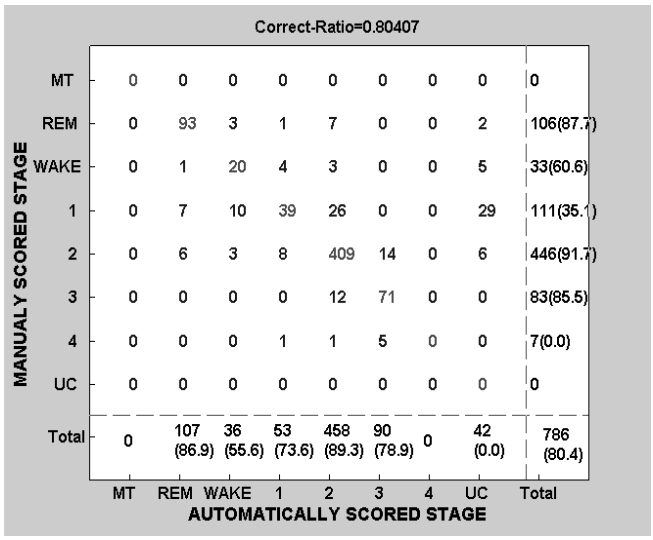

Fig 7. Example table of comparison between Visual scored and Automatically scored sleep structure of normal control

Another significant result is that our algorithm enhanced the conventional low reliability in applying to the abnormal subjects. In this experiment, even for the complex recordings of OSA, this architecture showed higher agreement rate (74 % with RBSU only and 85 % with CBSU) compared with the inter-scorer agreement rate (73%). Fig 8 and Fig 9 shows the example resulted from application of our algorithm to a normal control subject .

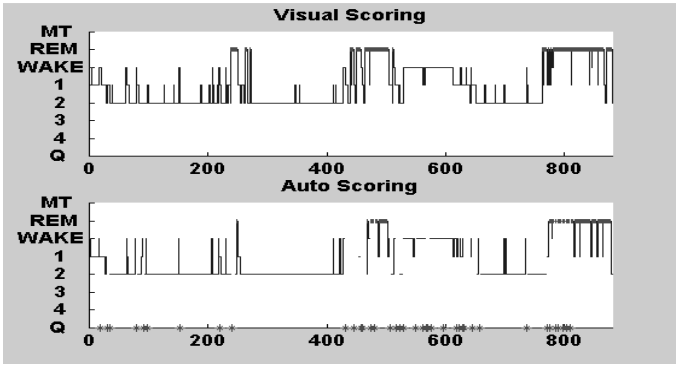

Fig 8. Example Hypnogram of Visually scored and Automatically scored sleep structure of OSA patient

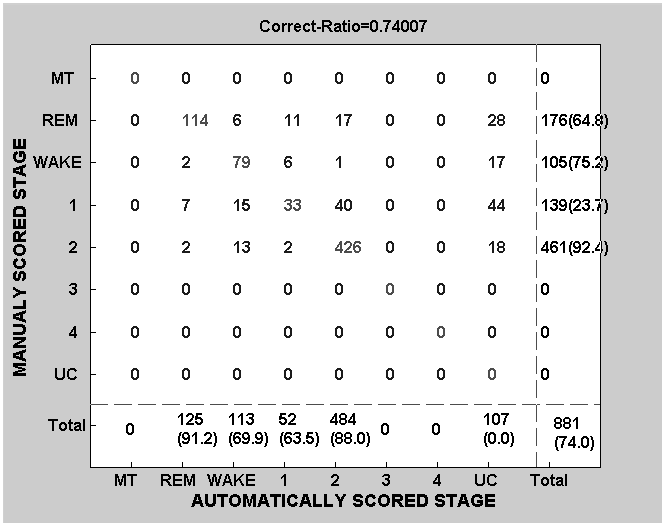

Fig 9. Example table of comparison between Visual scored and Automatically scored sleep structure of OSA patient

Furthermore our system has additional two major advantages over other analytical approaches, i.e. the explanation facility and the learning facility. In the medical decision system, the explanation of reasoning is essential function to clinicians. In this system, the rule-based scoring can be explained by the set of applied rules and its abstracted type, i.e. rule number, and the case-based scoring by the retrieved case and how to the similarity was measured. Another important advantage is that, by case acquisition, it can learn new problem-solving methods that cannot be represented by rules. The case-based reasoning engine uses both general experiences and subject dependent experiences by case accumulation during the scoring process.

IV. DISCUSSION

The effect of communication between SPU and RBSU is mainly the efficiency in time consuming. In the sense of correctly matched ratio between Visual human scoring and Automatic scoring is the same for conventional rule-based method and our algorithm. While time consuming was 21.5% of the conventional one in our test. Enhancement with augmented information is not implemented so well but it seems so promising.

V. CONCLUSION

In this study we automated sleep stage scoring which is core process of Polysomnography analysis by developing sleep stage scoring expert system with modular RBSU and SPU. And furthermore we improved conventional rule-based approach by importing communication between units to achieve higher time efficiency and correctness of reasoning.

The results of our experiment are promising. The decrease of time consuming resulting from using modular architecture and communication is the first significant result. So current claim is that a multi-staged rule-based reasoning system with inter-unit communication seems to be an efficient and exact

tool for sleep stage scoring. And if it is fused to another type of expert system, i.e. case-based reasoning, more correctness can be achieved and appropriate in the sense of mimicking human scoring.

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